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⑬ Applicant: FUJITSU LIMITED  
1015, Kamikodanaka Nakahara-ku  
Kawasaki-shi Kanagawa 211(JP)

⑬ Inventor: Noguchi, Yoshihumi  
4-21-24, Shakujii-machi Nerima-ku  
Tokyo 177(JP)

⑬ Inventor: Endoh, Hiroyuki  
1-24-9, Fujigaoka Midori-ku  
Yokohama-shi Kanagawa 277(JP)

⑬ Inventor: Ono, Kouichi  
1-40-7, Shinshikawa Midori-ku  
Yokohama-shi Kanagawa 227(JP)

⑬ Representative: George, Sidney Arthur et al,  
GILL JENNINGS & EVERY 53-54 Chancery Lane  
London WC2A 1HN(GB)

⑭ Direct relay equipment.

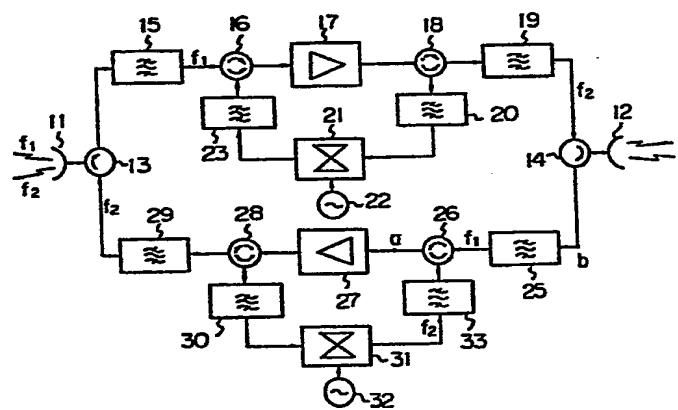
⑭ A direct relay equipment includes a first antenna (11), a second antenna (12), an up direction circuit (15-23) connected from the first antenna via a first circulator (13) to the second antenna via a second circulator (14), and a down direction circuit (25-33) connected from the second antenna via the second circulator to the first antenna via the first circulator. In the up direction circuit and the down direction circuit, a received signal having a frequency  $f_1$  from the first (or second) antenna is amplified by a microwave amplifier (17,27), the output of the microwave amplifier is converted to a signal having a frequency  $f_2$  (sending frequency), the signal having a frequency  $f_2$  is amplified by the same amplifier, and the amplifier signal having a frequency  $f_2$  is sent out from the second (or first) antenna.

EP 0 118 997 A2

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Fig. 2



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DIRECT RELAY EQUIPMENT

This invention relates to a frequency-shift type direct relay equipment for microwave amultiplex radio relay systems.

The development of field effect transistors for 5 microwave amplification has made it possible to amplify directly the microwave signals, and therefore possible to constitute a direct relay device for directly amplifying and relaying microwave signals in microwave multiplex radio systems. However, in this type of direct relay 10 equipment, the receiving frequency is different from the transmitting frequency. Therefore, the received signals must be amplified through a microwave amplifier, converted into a transmitting frequency through a mixer, and the converted signals amplified and transmitted. Hence, in 15 this type of equipment, an up circuit and a down circuit each need two amplifiers, so that the direct relay circuit as a whole needs four amplifiers, to amplify the received signals and the transmitted signals, respectively. Microwave amplifiers are expensive components, so the 20 direct relay equipment becomes expensive no matter how its construction is simplified.

It has previously been proposed to amplify the received signals and the transmitted signals having a shifted frequency through a single microwave amplifier. 25 However, problems arose with regard to interference between the received signals and the transmitted signals, and strict characteristics are required for the band-pass filters. These problems have not been previously solved.

An object of the present invention is to reduce 30 interference between the received signals and the transmitted signals, and to mitigate the strict requirements for the band-pass filter characteristics in a frequency-shift type direct relay equipment which employs a single microwave amplifier.

According to the invention there is provided a direct relay equipment, characterised by a first antenna and a second antenna; a first band-pass filter which is connected to the first antenna via a first circulator, 5 and which has a centre frequency equal to that of a received signal; a second circulator which receives an output of the first band-pass filter; a second band-pass filter which receives an output of the first band-pass filter fed through forward coupling of the second circulator, and which has a centre frequency equal to that of a transmitted signal; a first amplifier which receives an output which is reflected by the second band-pass filter back to the second circulator, and which is fed through forward coupling of the second circulator; 10 a third circulator which receives an output of the first amplifier; a third band-pass filter which receives an output of the first amplifier fed through forward coupling of the third circulator, and which has a centre frequency equal to that of the received signal; a 15 first mixer which receives an output of the third band-pass filter to convert it into the transmitting frequency signal, and which applies the converted signal via the second band-pass filter to the first amplifier; a fourth band-pass filter which receives an output which 20 is fed at the transmitting frequency from the first amplifier to the third circulator, which is reflected by the third band-pass filter back to the third circulator, and which is introduced via forward coupling of the third circulator; a fourth circulator which applies an 25 output of the fourth band-pass filter to the second antenna; a fifth band-pass filter which is connected to the second antenna via the fourth circulator, and which has a centre frequency equal to that of the received signal; a fifth circulator which receives an output 30 of the fifth band-pass filter; a sixth band-pass filter 35 of the fifth band-pass filter; a sixth band-pass filter

which receives an output of the fifth band-pass filter fed through forward coupling of the fifth circulator, and which has a centre frequency equal to that of the transmitted signal; a second amplifier which receives

5 an output which is reflected by the sixth band-pass filter back to the fifth circulator, and which is fed through forward coupling of the fifth circulator; a sixth circulator which receives an output of the second amplifier; a seventh band-pass filter which receives

10 an output of the second amplifier sent through forward coupling of the sixth circulator, and which has a centre frequency equal to that of the received signal; a second mixer which receives an output of the seventh band-pass filter to convert it into the transmitting

15 frequency signal, and which applies the converted signal via the sixth band-pass filter to the second amplifier; an eighth band-pass filter which receives an output which is sent at the transmitting frequency from the second amplifier to the sixth circulator, which is

20 reflected by the seventh band-pass filter back to the sixth circulator, and which is introduced via forward coupling of the sixth circulator, the output of the eighth band-pass filter being supplied via the first circulator to the first antenna.

25 Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which

Figure 1 is a block diagram of one example of a conventional direct relay equipment;

30 Figure 2 is a block diagram of one embodiment of a direct relay equipment according to the present invention; and

Figures 3A, 3B and 3C show block diagrams of

peripheral circuits of a mixer shown in Figure 2.

Figure 1 shows a conventional frequency-shift type direct relay device. The circuit shown in Figure 1 is used as the up or the down circuit. The received signal of, for example, 6000 MHz is received from an antenna 1, and an interference wave is removed by a filter 2. An amplifier 3 effects low level amplification and the output of the amplifier 3 is supplied to a filter 4, where an image signal is removed. The output of the filter 4 is supplied to a mixer 5. A shift generator 6 produces an oscillation at a shift frequency, for example 160 MHz, so that the mixer 5 generates an output having a frequency of 6,160 MHz. The output of the mixer 5 is fed to a filter 7, by which any spurious signal is removed from the received signal. An amplifier 8 effects high level amplification, and the output of the amplifier 8 is supplied to a filter 9. The output of the filter 9 is fed to an antenna 10.

In the circuit shown in Figure 1, two amplifiers 3 and 8 are required, as already mentioned.

Figure 2 is a block diagram illustrating an embodiment of the present invention. The equipment comprises first and second antennas 11 and 12, circulators 13 and 14 coupled to the antennas, band-pass filters 15 and 25 having a centre frequency  $f_1$ , circulators 16, 26, 18 and 28, microwave amplifiers 17 and 27, band-pass filters 19 and 29 having a centre frequency  $f_2$ , band-pass filters 20 and 30 having a centre frequency  $f_1$ , mixers 21 and 31, oscillators 22 and 32, and band-pass filters 23 and 33 having a centre frequency  $f_2$ . The frequency  $f_1$  signal received by the first antenna 11 is applied to the band-pass filter 15 via the circulator 13. The band-pass filter 15 removes signals of undesired

bands, and a received signal having the frequency  $f_1$  only is applied to the circulator 16.

The circulator 16 has a coupling direction as indicated by the solid line arrow. Here, since the 5 band-pass filter 23 has the center frequency  $f_2$ , the signal having the frequency  $f_1$  heading from the circulator 16 to the band-pass filter 23 is reflected back to the circulator 16, and is applied to the microwave amplifier 17 via the circulator 16. The output of 10 the amplifier 17 is applied to the circulator 18, which has a coupling direction as indicated by the solid line arrow. Therefore, the received signal of the frequency  $f_1$  is added to the mixer 21 via the band-pass filter 20 having the center frequency  $f_1$ . This received signal 15 is mixed with the output of the oscillator 22 through the mixer 21, converted into a signal of the frequency  $f_2$ , applied to the band-pass filter 23 having the center frequency  $f_2$ , and is added to the amplifier 17 via the circulator 16.

20 The signal having the frequency  $f_2$  is amplified through the amplifier 17, and the amplified output is added to the circulator 18. Since the band-pass filter 20 has the center frequency  $f_1$ , as mentioned above, the signal having the frequency  $f_2$  is reflected, 25 enters into the circulator 18, and is applied, via the circulator 18, to the band-pass filter 19 having the center frequency  $f_2$ . The signal which is passed through the band-pass filter 19 is sent to the second antenna 12 via the circulator 14, and is transmitted 30 at a transmitting frequency  $f_2$ .

The signal having the frequency  $f_1$  received by the second antenna 12 is also amplified by the amplifier 27, in the same manner as described above, subjected to frequency conversion through the mixer 31, amplified again through the amplifier 27, and is transmitted at 35 the transmitting frequency  $f_2$  from the first antenna 11.

Thus, the signal having the frequency  $f_1$  received by

the first antenna 11 is transmitted at the frequency  $f_2$  from the second antenna 12, and the signal having the frequency  $f_1$  received by the second antenna 12 is transmitted at the frequency  $f_2$  from the first antenna 11.

- 5 Namely, the signal is amplified through a signal amplifier 17 or 27; making it possible to economically construct the direct relay device. The amplifiers 17, 27 have an automatic gain control (AGC) function to produce a stable transmitting power. Therefore, even  
10 when there are variations in the received power, the relay operation can be stably carried out. The AGC function may be obtained by any known circuit arrangement.

In the above-described direct relay equipment, the coupling directions of the circulators 16, 18, 26 and 28  
15 are selected as indicated by the solid line arrows, in order to reduce the interference caused by roundabouts, as explained below.

The direction in which the signal received by the first antenna 11 is transmitted from the second antenna 12 is regarded as the up direction, and the direction in which the signal received by the second antenna 12 is transmitted from the first antenna 11 is regarded as the down direction.

The following is a consideration of the effect caused by the signal transmitted in the up direction which enters by roundabout ways into the down direction circuit. The transmitted  $f_2$  frequency having a power of  $P_t$  in the up direction is applied to the band-pass filter 25 through a reverse coupling of the circulator 14, sent  
25 to the circulator 26 via the band-pass filter 25, sent to the amplifier 27 through a reverse coupling of the circulator 26, is amplified and sent to the band-pass filter 30 through a forward coupling of the circulator 28, mixed with the output of the oscillator 32 in the  
30 mixer 31, converted into a signal similar to a received signal in the down direction, sent to the circulator 26 via the band-pass filter 33, and is sent to the ampli-  
35

fier 27 through a forward coupling of the circulator 26.

Therefore, an undesired signal  $U$  at the input point a of the amplifier 27 arrives via a circuit which consists of 14 + 25 + 26 (reverse coupling) + 27 + 28 (forward coupling) + 30 + 31 + 33 + 26 (forward coupling). In this case, the signal is subjected to attenuation  $L_{14}$  caused by reverse coupling of the circulator 14, attenuation  $LF_{25}$  which the band-pass filter 25 having the center frequency  $f_1$  gives to the signal of the frequency  $f_2$ , attenuation  $L_{26}$  caused by a reverse coupling of the circulator 26, amplification by the gain  $G$  of the amplifier 27, attenuation  $LF_{30}$  caused by the band-pass filter 30 having the center frequency  $f_1$ , conversion loss  $\eta$  caused by the mixer 31, and attenuation  $LF_{33}$  caused by the band-pass filter 33 having the center frequency  $f_2$ . Attenuation by forward coupling of the circulators 26 and 28 can be virtually neglected. Therefore, the undesired signal  $U$  at the point a is given by the following equation,

$$20 \quad U = Pt - L_{14} - LF_{25} - L_{26} + G - LF_{30} - LF_{33} - \eta \quad \dots (1)$$

If the coupling direction of the circulator 26 is reversed, as indicated by the dotted line arrow, the signal is sent from the band-pass filter 25 to the amplifier 27 through a forward coupling of the circulator 26, wherein the attenuation is negligibly small. In this case, an undesired signal  $U'$  at the point a is given by the following equation,

$$30 \quad U' = Pt - L_{14} - LF_{25} + G - LF_{30} - LF_{33} - \eta \quad \dots (2)$$

If the undesired signals  $U$  and  $U'$  have levels smaller than that of a received signal  $Pr$  in the down direction, the amplifier 27 properly exhibits the AGC function. For this purpose, the condition  $Pr > U$  or  $Pr > U'$  must hold true, as shown by the following equations,

$$Pr > Pt - L_{14} - LF_{25} - L_{26} + G - LF_{30} - LF_{33} - \eta$$

$$\therefore \text{LF25} + \text{LF30} + \text{LF33} > \text{Pt} - \text{L14} - \text{L26} - \eta + \text{G} - \text{Pr} \quad \dots (3)$$

Further,

$$\begin{aligned} \text{Pr} &> \text{PT} - \text{L14} - \text{LF25} + \text{G} - \text{LF30} - \text{LF33} - \eta \\ 5 \quad \therefore \text{LF25} + \text{LF30} + \text{LF33} &> \text{Pt} - \text{L14} - \eta + \text{G} - \text{Pr} \quad \dots (4) \end{aligned}$$

That is, as will be obvious from a comparison of equation (3) with equation (4), if the coupling direction of the circulator 26 is selected as indicated by the 10 solid line arrow, the attenuation quantities of the band-pass filters 25, 30, and 33 can be reduced by an amount corresponding to attenuation L26, by the reverse coupling of the circulator 26. This indicates that construction of the band-pass filters 25, 30, and 33 15 can be simplified.

The advantage which stems from the coupling direction of the circulator 26 that is set as indicated by the solid line arrow also holds true for the circulator 16. That is, by setting the coupling direction as indicated 20 by the solid line arrow, the construction of the band-pass filters 15, 20, and 23 can be simplified.

Next is considered the effect caused when the received signal in the up direction enters into the down direction circuit by roundabout ways. The received  $f_1$  25 signal having power of  $\text{Pr}'$  in the up direction introduced through the band-pass filter 15 is amplified through the amplifier 17, sent to the circulator 14 via a reverse coupling of the circulator 18 and band-pass filter 19, and is sent to the band-pass filter 25 via a reverse 30 coupling of the circulator 14. In this case, if the circulator 18 has a coupling direction as indicated by the solid line arrow, the undesired signal  $U_1$  at the point b is given by the following equation,

$$U_1 = \text{Pr}' + \text{G} - \text{L18} - \text{LF19} - \text{L14} \quad \dots (5)$$

35 as in the above-mentioned case. Here, L18 denotes attenuation by the reverse coupling of the circulator 18, and LF19 denotes attenuation caused by the passage of a

signal having the frequency  $f_1$  through the band-pass filter 19 having the center frequency  $f_2$ .

When the circulator 18 has the coupling direction as indicated by the dotted line arrow, the received 5 signal  $Pr'$  is sent to the band-pass filter 19 via a forward coupling of the circulator 18, wherein the attenuation is negligibly small. Therefore, the undesired signal  $Ul'$  at the point b is given by the following equation,

10  $Ul' = Pr' + G - LF19 - L14 \quad \dots (6)$

In order for the amplifier 27 to properly exhibit the AGC function, the received signal  $Pr$  in the down direction must have a level which is greater than that of the undesired signals  $Ul$  and  $Ul'$ , as shown by the 15 following equations,

$$\begin{aligned} Pr &> Pr' + G - L18 - LF19 - L14 \\ \therefore LF19 &> G - L18 - L14 + Pr' - Pr \end{aligned} \quad \dots (7)$$

Further,

$$\begin{aligned} Pr &> Pr' + G - LF19 - L14 \\ \therefore LF19 &> G - L14 + Pr' - Pr \end{aligned} \quad \dots (8)$$

That is, by setting the coupling direction of the circulator 8 as indicated by the solid line arrow, the attenuation quantity of the band-pass filter 9 for the signal of the frequency  $f_1$  can be reduced by the attenuation quantity caused by a reverse coupling of the 25 circulator 8, as is obvious from a comparison of equation (6) with equation (7). This indicates that construction of the band-pass filter 19 can be simplified. Similarly, by setting the coupling direction of the circulator 28 30 as indicated by the solid line arrow, construction of the band-pass filter 29 can be simplified.

Figures 3A, 3B, and 3C show peripheral circuits of the mixer shown in Fig. 2. In the mixer circuit shown in Fig. 3A, an isolator 41 is usually connected between 35 the mixer 21 (or 31) and the filter 23 (or 33) so that an echo frequency wave is absorbed. As shown in Fig. 3B, an isolator 42 may be connected between the

mixer 21 (or 31) and the filter 20 (or 30); that is, in the input side of the mixer 21 (or 30). In the circuit shown in Fig. 3B, the same effect as that of Fig. 3A can be obtained. Isolators 43, 44 may be connected at both the 5 input side and the output side of the mixer circuit 21, as shown in Fig. 3C. Further, the isolators 41, 42, 43, and 44 can be included in the mixers 21 or 31, respectively.

In the present invention, the unnecessary wave 10 having, for example, a frequency  $f_x$ , which penetrates from the output terminal of the mixer 21 or 31 can be directed via the isolator 41 (or 42, 43, 44) to a dummy load 41a (or 42a, 43a, 44a).

As described above, by setting the coupling directions of the circulators 16, 18, 26, and 28 as indicated by the solid line arrows, the entrance of the transmitted signals of the up direction or the down direction into the circuit of the down direction or of the up direction through roundabout ways can be reduced, and further, 15 the received signals of the up direction or the down direction entering into the circuit of the down direction or of the up direction through roundabout ways can be reduced. Therefore, the relay amplification operation 20 can be stably performed despite the simplified construction of the band-pass filters.

According to the present invention as explained above, the received signal of the frequency  $f_1$  is amplified through the amplifiers 17 and 27, converted into a signal having the frequency  $f_2$  through the 30 mixers 21 and 31, and the converted signal is amplified by the amplifiers 17 and 27. Accordingly, the received signal and transmitted signal are amplified by the same amplifier, making it possible to economically utilize the microwave amplifier. Furthermore, by specifying the 35 coupling directions of the circulators, interference between the signal of the up direction and the signal of the down direction can be reduced, and the strict

requirements for the band-pass filter characteristics can be alleviated, enabling the band-pass filters to be economically constructed.

CLAIMS

1. A direct relay equipment, characterised by a first antenna (11) and a second antenna (12); a first band-pass filter (15) which is connected to the first antenna via a first circulator (13), and which has a 5 centre frequency equal to that of a received signal ( $f_1$ ); a second circulator (16) which receives an output of the first band-pass filter (15); a second band-pass filter (23) which receives an output of the first band-pass filter fed through forward coupling of the 10 second circulator, and which has a centre frequency equal to that of a transmitted signal ( $f_2$ ); a first amplifier (17) which receives an output which is reflected by the second band-pass filter back to the second circulator, and which is fed through forward coupling of the second 15 circulator; a third circulator (18) which receives an output of the first amplifier; a third band-pass filter (20) which receives an output of the first amplifier fed through forward coupling of the third circulator, and which has a centre frequency equal to that of the 20 received signal ( $f_1$ ); a first mixer (21) which receives an output of the third band-pass filter to convert it into the transmitting frequency signal, and which applies the converted signal via the second band-pass filter to the first amplifier; a fourth band-pass filter (19) 25 which receives an output which is fed at the transmitting frequency from the first amplifier to the third circulator which is reflected by the third band-pass filter back to the third circulator, and which is introduced via forward coupling of the third circulator; a fourth circulator (14) which applies an output of the fourth 30 band-pass filter to the second antenna; a fifth band-pass filter (25) which is connected to the second antenna via the fourth circulator, and which has a centre frequency equal to that of the received signal ( $f_1$ ); a fifth 35 circulator (26) which receives an output of the fifth

band-pass filter; a sixth band-pass filter (33) which receives an output of the fifth band-pass filter fed through forward coupling of the fifth circulator, and which has a centre frequency equal to that of the transmitted signal ( $f_2$ ); a second amplifier (27) which receives an output which is reflected by the sixth band-pass filter back to the fifth circulator, and which is fed through forward coupling of the fifth circulator; a sixth circulator (28) which receives an output of the second amplifier; a seventh band-pass filter (30) which receives an output of the second amplifier sent through forward coupling of the sixth circulator, and which has a centre frequency equal to that of the received signal ( $f_1$ ); a second mixer (31) which receives an output of the seventh band-pass filter to convert it into the transmitting frequency signal, and which applies the converted signal via the sixth band-pass filter to the second amplifier; an eighth band-pass filter (29) which receives an output which is sent at the transmitting frequency from the second amplifier to the sixth circulator, which is reflected by the seventh band-pass filter back to the sixth circulator, and which is introduced via forward coupling of the sixth circulator, the output of the eighth band-pass filter being supplied via the first circulator to the first antenna.

2. A direct relay equipment according to claim 1, characterised in that a respective isolator (41-44) is connected to the output and/or the input of the first mixer (21) and the second mixer (31).

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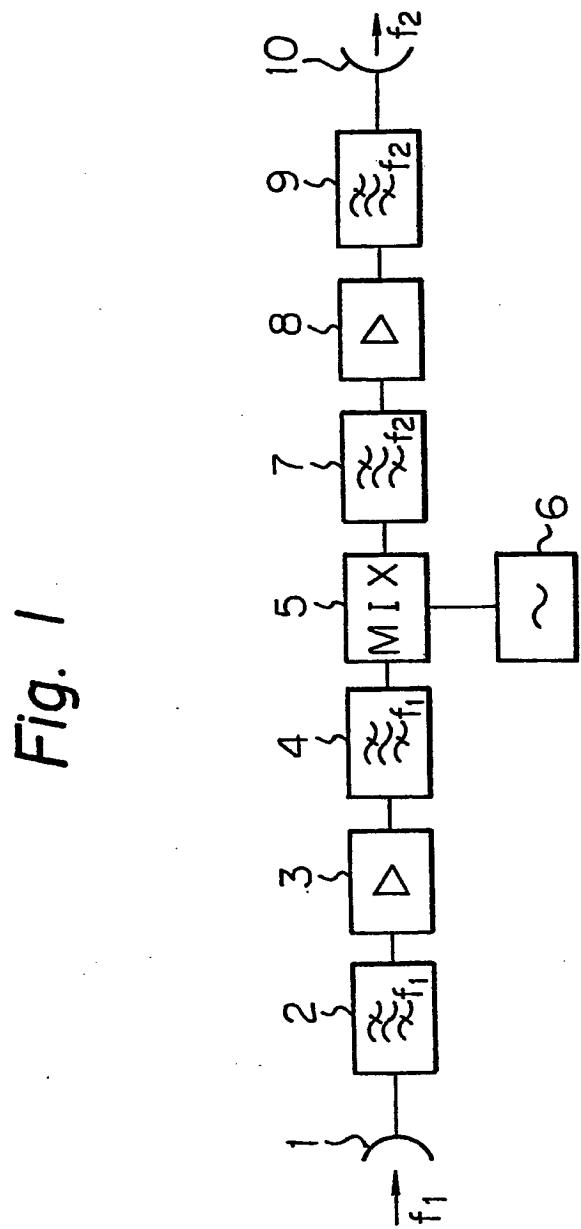
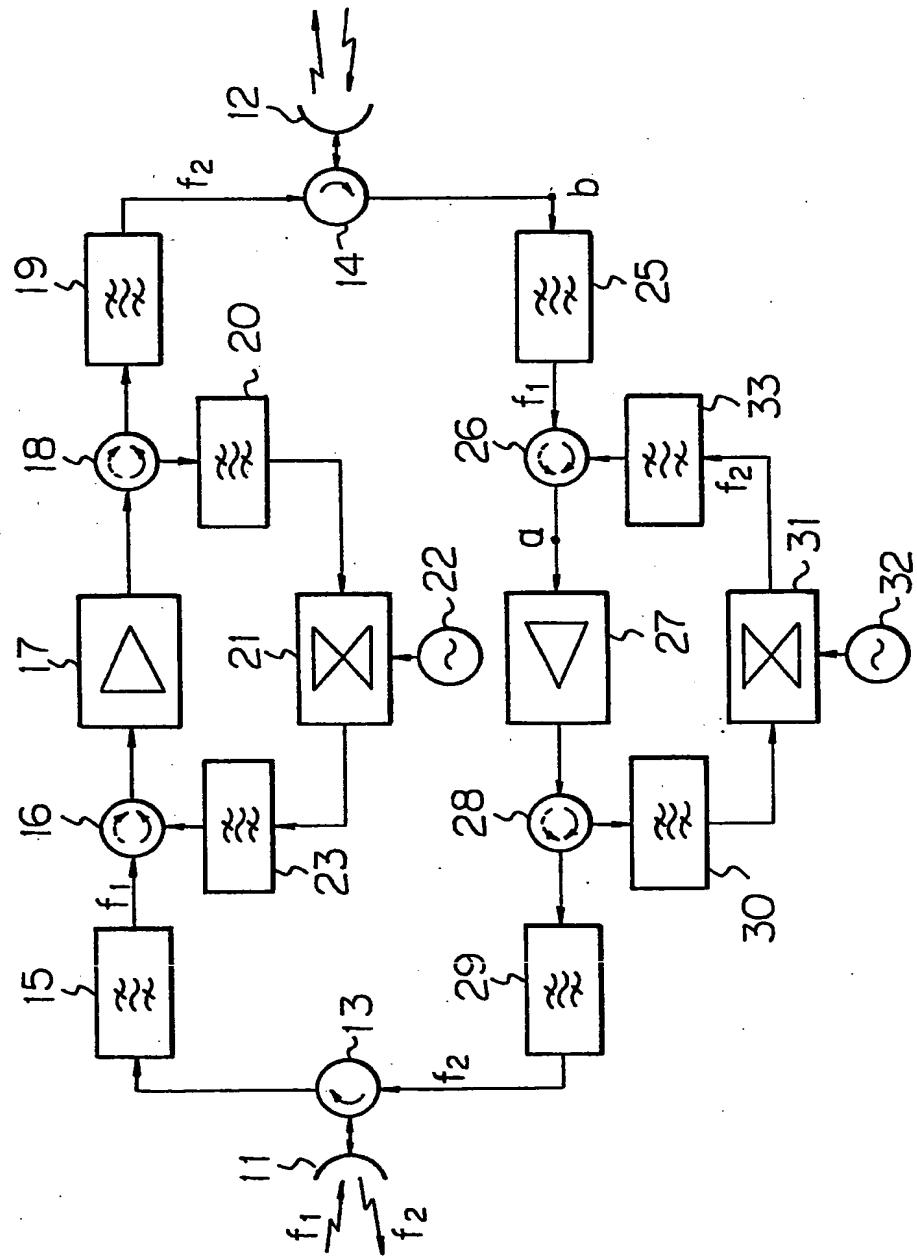
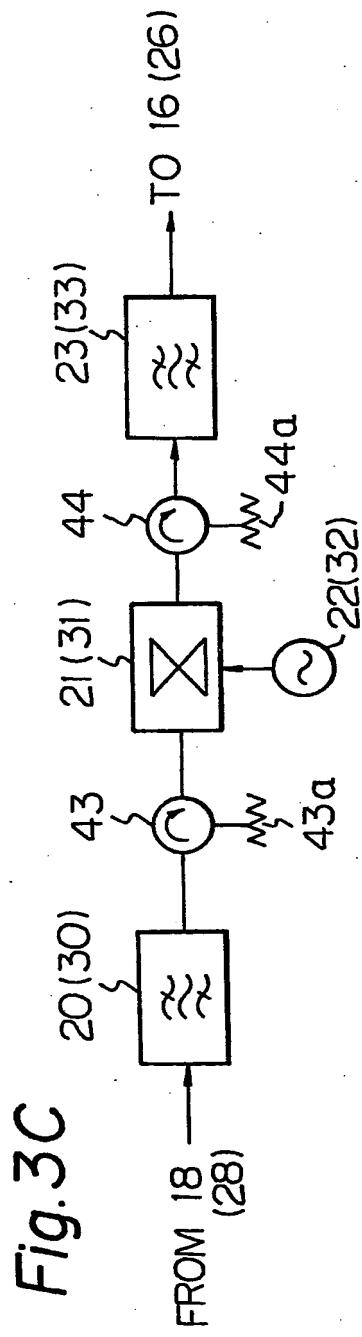
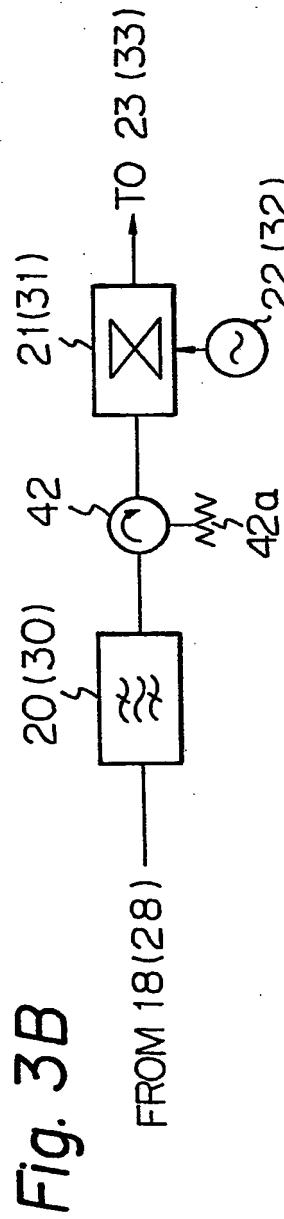
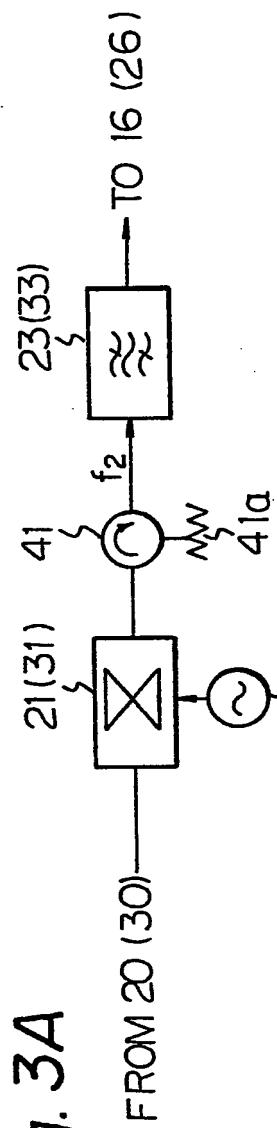


Fig. 1

Fig. 2



3/3



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